SEARCHING FOR AN ACIDIC AQUIFER IN THE RÍO TINTO BASIN. FIRST GEOBIOLOGY RESULTS OF MARTE PROJECT

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Introduction: Among the conceivable modern habitats to be explored for searching life on Mars are those potentially developed underground. Subsurface habitats are currently environments that, under certain physicochemical circumstances, have high thermal and hydrochemical stability [1, 2]. In planets like Mars lacking an atmospheric shield, such systems are obviously protected against radiation, which strongly alters the structure of biological macromolecules.

Low porosity but fractured aquifers currently emplaced inside ancient volcanosedimentary and hydrothermal systems act as excellent habitats [3] due to its thermal and geochemical properties. In these aquifers the temperature is controlled by a thermal balance between conduction and advection processes, which are driven by the rock composition, geological structure, water turnover of aquifers and heat generation from geothermal processes or chemical reactions [4]. Moreover, microbial communities based on chemolithotrophy can obtain energy by the oxidation of metallic ores that are currently associated to these environments. Such a community core may sustain a trophic web composed of non-autotrophic forms like heterotrophic bacteria, fungi and protozoa.

The MARTE project [5] combines both the acquisition of scientific knowledge on Terrestrial cryptic communities to be found in ancient hydrothermal/volcanosedimentary systems, which may be common on Mars, and the technology development for detecting them in the Martian underground. Such a complex task demands robotic and instrument systems for exploring, sampling, and analyzing subsurface samples. This paper shows the first geobiological data recovered during the "ground truth" drilling operations from the MARTE experiment (see ref. 6) that were performed recently in the ancient hydrothermal system of the Río Tinto Basin. MARTE project objectives are summarized in [5, 6].

The ground truth drilling, the first activity of the MARTE project, started in September '03 and is taking place in Peña de Hierro, near the source waters of the Tinto River. The river is sourced in the Iberian Pyrite Belt [7, 8], one of the largest deposits of sulfide minerals in the world.

Geological and hydrochemical settings: The Tinto River Basin has its source close to Nerva and Ríotinto villages see [6] in the southern margin of the Sierra de Aracena that is located in the Iberian Pyritic Belt. This extensive geological unit is made up by Late Devonian to middle Carboniferous volcanosedimentary stacks that have recorded hydrothermal activity in the form of thick and massive metallic ores promoted by a cortical melting event [7, 9]. The hydrothermal fluids injected massive ore bodies and sedimentary deposits [9] enriched in metallic and transition elements. Different Hercynian events strongly induced folding, faulting and thrusting in the volcanosedimentary materials [10].

The sedimentary deposits at Peña de Hierro is made up of, from the bottom to the top, hydrothermalized volcanosediments, stockworked pyrite, massive pyrite, green volcanic tuffs, andesitic aglomerates, green ashes, and purple shales overlain by grey shales originated during the middle to late Carboniferous dismantling of the orogen. Silica and iron mobilization/precipitation during a hydrothermally driven diagenesis provoked the extreme reduction of material porosity. The Hercynian movements southward caused an intensive tectonic activity, which culminated with overturning the geological structure and thrusting the sedimentary stacks along the Río Tinto Basin [10]. In the area of Peña de Hierro such an activity is recognized as NW-SE and NE-SE oriented folding and faulting, as well as a large thrusting face of E-W direction.

Underground oxidation of the metallic massif ($4{\cdot}FeS_2 + 10{\cdot}H_2O + 7{\cdot}O_2 \Rightarrow 4{\cdot}Fe^{3+} + 8{\cdot}SO_4^{=} + 20{\cdot}H^+$) mediated by microbes has been claimed to be the main process that originates the acidic brines (pH=0.9-3) found in the subsurface waters [8]. Some physicochemical requirements (temperature and water availability) are also needed to generate such unusual hydrochemistry [8].

By considering the hydrological and geological features of the potential drilling sites around Peña de Hierro, we deduce that the aquifer storage and replenishment is driven by basement faulting, which conducts the infiltrated rainwater from the subsurface to the metallic ores. A field surveying suggests that acidic springs are associated with faults. Moreover, an electromagnetic survey of potential drilling sites detected sharp subsurface horizons characterized by values of conductivity comparable to the conductivity of the surface acidic waters. These observations support the existence of fractures that conduct acidic brines into the Rio Tinto headwaters.

Ground truth drilling in 2003. Subsurface geology: Two sites with different geological characteristics were drilled in 2003 to explore and sample the geobiology of the pyritic ore and the acidic aquifer. The first site (Borehole 4) was situated on the gossan of Peña de Hierro that is emplaced on hydrothermalized tuffs and stockworked sulfides by acidic weathering of sulfuric solutions. Drilling achieved a depth of 166.35 meters of cores with good core recovery. From the mineralogical and hydrochemical characteristics of the samples, four different zones can be inferred: an oxidized zone (0 to -35 m), a vadose oxidizing area (-35 to –90 m), an aquifer (-90 to –150 m) and an impermeable bottom (under –150 m). The **oxidized zone** was sampled at the top of the borehole and is composed by iron oxyhydroxydes, some phyllosilicates and chert showing high porosity in form of voids and fractures. In this zone the water pH is around 6.5. The **vadose oxidizing zone** shows oxides, oxyhydroxide and sulfide under acidic to neutral conditions (water pH between 3.9 and 7.3). These former two zones lay above the water table that was found at around –89 meters. Below –90 m the mineral association of the **aquifer zone** changes to dark oxides and sulfides. In this zone, the rock is highly cracked and displays vertical and oblique fractures. The water pH decreases in some levels to 3.3, although some horizons showing neutral pH are found. At the bottom of the borehole and below -150 m, non-fractured and low porosity cores occur made of dark phyllosilicates with disseminated pyrite were obtained. As the phyllosilicates prevent water infiltration, this zone should correspond to an impermeable bottom, which is consistent with the pH values.

Molecular biology and microbiology analyses have detected biological activity associated to the pyritic ore below 80 m depth. Simple microscope observations of gossan from the oxidized and vadoze zone samples revealed fungal filaments some of them coated with iron oxyhydroxides what support its autochthony. Differences in mineralogy and hydrochemistry observed at Borehole 4 suggest at least two different habitats that could be occupied by distinctive microbial communities. The first one would be composed by prokaryotic and eukaryotic aerobic heterotrophs (fungi) feeding on organic matter that can be transported subsurface by water seeping into the porous sediments. The lower, vadose and aquifer, communities would be represented by chemolithotrophs supported by reduced minerals such as pyrite. Differences in the water availability must play an important role in habitat oxygenation and stability.

The second site (Borehole 1) was drilled on the Carboniferous grey shales that are the youngest lithostratigraphical unit occurring in the basement of Tinto River headwaters. The site is surrounded by different acidic springs and it is near the thrusting face that has been hypothesized to act as a main reservoir of the acidic aquifer. Although the sampled cores showed a 59-meter thick monotonous lithology made of gray shales, three different horizons with distinctive alteration degree were recognized: weathering zone (0 to –13 m), non-altered zone (-13 to –40 m) and aquifer (bellow –40 m). The upper zone undergoes a decreased alteration from the top to the bottom, which becomes nonexistent in the unaltered shale, under –13 m. However, under –40 m, the sampled cores display highly altered and tectonically fractured phyllosilicates with some dissolution evidences. Although pH measurements have been obtained, differences in alteration suggest the existence of acidic waters below –40 m.

Conclusions: Differences in mineralogy and hydrochemistry observed at Borehole 4 suggest at least two different habitats that could be occupied by distinctive microbial communities. The first one would be composed by prokaryotic and eukaryotic aerobic heterotrophs (fungi) feeding on organic matter that can be transported subsurface by water seeping into the porous sediments or be biosynthesized *in-situ*. The lower, vadose and aquifer, communities would be represented by chemolithotrophs supported by reduced minerals such as pyrite. Differences in the water availability must play an important role in habitat oxygenation and stability.

References: [1] Pedersen K. (1993) *Earth-Science Rev*., 34, 243-260. [2] Wellsbury P K et al. (1997) *Nature*, 388, 573-576. [3] Baker B J and Banfield J F (2003) *FEMS Microbiol. Ecol.* 44(2), 139-152. [4] Rohwerder T et al. (1998) *Thermochimica Acta*, 309, 79-85. [5] Stoker G H (2003) *LPS XXXIV,* Abstract #1076. [6] Stoker C et al. LPSC 35, 2004. [7] Leistel J M (1998) *Miner. Deposita*, 33(2), 2-30. [8] Fernández-Remolar D et al. (2003) *JGR* 108(E7), 10.1029/2002JE001918. [9] Solomon M F et al. (2002). *Geology,* 30(1), 87-90. [10] Quesada, C. (1998). *Miner. Deposita*, 33, 31-44.